RESEARCH ARTICLE OPEN ACCESS

Construction Planning For The Next Generation Of Rural Coastal India

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Abstract
Construction activities in the rural coast is a typical phenomenon which involves social, psychological, economical, environmental, geological, political, global, national as well as local issues of concern. Safe reconstruction for the rural coastal community after the 2004 devastating tsunami was the common will of all the twelve affected countries. In the subsequent tsunami of 2011, Japan experienced a multiple disasters and could not be able to manage things. It was proved by many factors like lack of land use planning, quality of construction, provision of basic amenities, health and total safety for Indian Tsunami reconstruction. Therefore, scientific and technological based approach only can give a better solution. For a developing country like India, having more rural based communities, the problem is serious and it becomes necessary to have the construction activities with a control system to achieve a permanently safer system. The problem is also aggravated for the next decade invited by the expected sea level rise and global warming issues, scarcity of water and other essential construction materials and shortage of conventional power production. This paper brings out the concept of providing an appropriate planning for the overall safe reconstruction in the rural east coast of India for the next generation.
Key words: coastal planning, protection, renewable energy, tsunami reconstruction

I. Introduction

During the December 2004 Tsunami the housing stock along the East coast of India, as well as bridges and roads, suffered extensive damage by direct pressure from tsunami waves, and scouring damage was induced by the receding waves. Many of the affected structures consisted of non-engineered, poorly constructed houses belonging to the fishers (Alpa Sheth et al., 2006). It destroyed thousands of homes and displaced over 500,000 people in Indonesia (IOM Report, 2005) and in Sri Lanka the Tsunami left half a million people homeless and the impacts intensified resource shortage, fuelled inflation, constrained government's fiscal capacity, and adversely affected housing reconstruction (Jayasuriya et al. 2005). Satoko and Kazuya (2012) presented a study conducted in North-eastern Japan prior to 2011 earthquake (EQ) and after 2011 EQ and Tsunami. The disastrous tsunami reached over 30m in height at several points, and more than 90% of deaths were related to drowning.

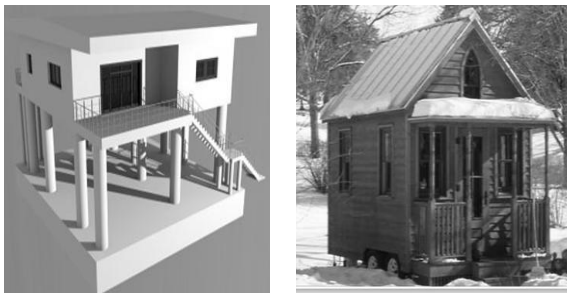
The scientists alert on the sea level rise which should be kept in mind while planning for the reconstruction. The Inter governmental Panel on Climate Change (IPCC-2001) published a guide to help policy makers by, among other things, providing potential scenarios for the end of 21st century. These projections received widespread support by many within the scientific community, though they have also been criticized as being too conservative. Some other sources have predicted global sea level rise of around 80 cm by the end of this century. Even before 2004 Tsunami, coastal zones and ecosystems in India were under heavy stress. Tata Energy Resource Institute (TERI) of India had made useful surveys and reported the impacts of agriculture, aquaculture and industrial developments on coastal ecosystems leading to the destruction of vast areas of mangroves.

During the last 20 years, India has experienced 10 major EQs that have claimed more than 35000 lives. Almost 58% of our total land mass is prone to EQs of moderate to very high intensity. India has a long coastline running 7516 km long and the entire coastal stretch of South India is exposed to Tsunami, cyclone, waves and storm surges. On an average, five to six tropical cyclones strike every year, of which two or three are very severe. More cyclones occur in the Bay of Bengal than in the Arabian Sea and every year the east coast is affected by cyclones and Tsunami. The Super Cyclone (1999), Thane cyclone (2010) and Tsunami 2004 claimed thousands of human lives devastating agricultural crops and rendering lakhs of people homeless.

A study conducted after the 2004 tsunami in 18 coastal hamlets along the south-east coast of India reiterates the importance of coastal mangrove vegetations and location characteristics of human inhabitation to protect lives and wealth from the fury of tsunami (Kathiresan and Rajendran, 2005). The tsunami caused human death and loss of wealth was decreased with the area of coastal vegetation, distance and elevation of human inhabitation from the sea. The aim of reducing future life loss and property damage can be achieved only by a long term commitment. Janakarajan (2009) examined the challenges of sea and level rise climate change impacts and disaster risk reduction strategies in Tamil Nadu state of India through research. It is concluded that the existing adaptation measures undertaken by the communities are adhoc and not sustainable in the long term.

The first suggestion by the Malaysian Government was to build houses outside a green zone of 3km from the shore line but was decisively rejected by the local authorities in Aceh (Regan, 2006). It was anticipated that a smaller tsunami wave than the 10+ metre event that occurred in 2004 would be sufficient for design. The assumption was that this event was rare and it was also stated that in the next 30-40 years that the return period of a tsunami in the area was of the order of 1 in 35 years (Wilkinson, 2005). The Indonesian government with International Organization for Migration (IOM) built 11000 pre-fabricated houses for vulnerable Acehnese homeless families. IOM's emergency response programme had provided them with three types of shelter either as tents or emergency shelters or transitional shelters.

Buildings can be created to withstand the EQs, but designers remain largely powerless in thwarting the destructive forces of a tsunami. But engineers hope to possibly change the way buildings designed in coastal regions. Renata (2011) had discussions with mailing engineers and concluded briefly in the aspect of the goal of Engineers. At the Tsunami in Japan, lots of buildings were flooded by Tsunami waves and some of them were moved by the waves. Ventasal (2012) tried some Tsunami resistant house design and Tsunami resistant building design example introduced by FDN Engineering was designed to withstand extreme forces including tsunami shown in figure 1(a). Engineers are designing methods and techniques to design a building on columns for coastal areas. Jay Shafer (2008) has come up with Tumbleweed houses which can be put nearly anywhere shown in figure 1(b). He declares that it produces less than 4 tons of greenhouse gases during a typical Minnesota winter. But for a rural coast it will not serve in India.



(a) FDN Design (Ventasal, 2012) (b) Tumbleweed houses (Jay Shafer, 2008)

Fig.1 Some promoted system of buildings

Jay Raskin et al (2009) reported about the tsunami evacuation buildings (TEB) as new risk management approach to the Cascadia EQ and tsunami. TEBs are important elements to insure schools, essential facilities, and government buildings able to meet their everyday purposes, and continue to function after the EQ and tsunami. Preliminary design, technical and social issues are considered, including tsunami dissipater to deflect wave energy away from the TEB and geotechnical and structural design to survive a magnitude 9EQ and near field tsunami. Japan has proposed an anti Tsunami system shown in figure 2. In total, of all the requirements, a planning for safety construction with control system becomes the prime need of the hour.

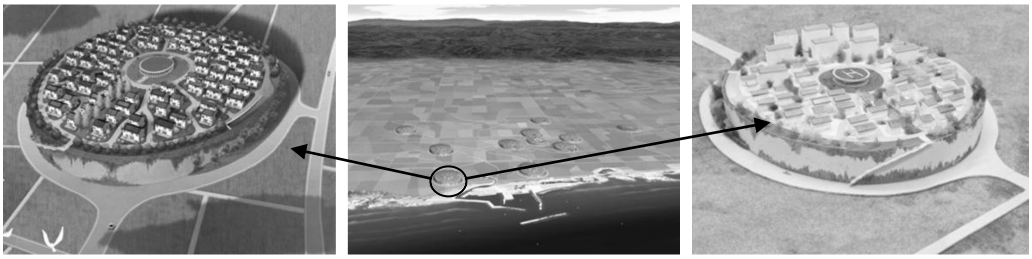


Fig. 2 A new Anti-tsunami Archipelago for Japan

Prabhakar et al (2011) give some critical review of civil engineering aspects to be adopted with tsunami's effects and the combination of EQs and tsunamis in mind. It also gives facts about characteristics of tsunami induced waves. Andhra Pradesh government constructed 1230 dwelling units in the proposed tsunami-resistant housing colonies for fishermen in the coastal villages of Vizianagaram district. Soil investigations were carried out in the proposed sites and recommendations/guidelines were given for better tsunami resistant building. The rescue and relief work undertaken in the Andaman and Nicobar islands and in mainland India after the tsunami was massive (Murty et al, 2006). A number of new initiatives undertaken by the government and non-governmental agencies were innovative and successful because full powers being given to all the eleven zonal chiefs.

Pittet et al (2007) reports on housing reconstruction in Tamil Nadu after the 2004 tsunami. Published by the Institute for Applied Sustainability to the Built Environment, this document illustrates the social, environmental and economic advantages of vernacular housing, and sets out to inform agencies involved in post-disaster recovery about the importance of recognizing and building upon local housing culture and building capacity. This article was useful for a range of agencies involved in post-disaster housing reconstruction in local community settings.

An estimated, 53290 homes were destroyed and 11694 houses damaged in Tamil Nadu (GoTN Report, 2008). The entire physical infrastructure, though sparing along the coast, was also destroyed, including facilities for fishing and related occupations. The damage was estimated at US$ 880 million. Multilateral organizations, donors, NGOs, religious organizations, civil societies, and corporations provided phenomenal logistic, monetary and technical support for housing reconstruction. Apart from the originally proposed number of houses, additionally 39692 houses are being constructed by NGOs in varying locations for Scheduled Castes, Scheduled Tribes and people below the poverty line. Construction of these houses was taken up for families whose houses were not damaged by tsunami. These families belong to the most disadvantaged sections of the society namely Irulas, fish workers and families who are living very close to the sea and face frequent disastrous situations.

After the tsunami, fishermen families opted for concrete houses instead of huts. Once their opinion was obtained, the model was then placed before district level committee for approval (GoTN Report, 2008). Environmental guidelines for building the infrastructure were followed. The type and design of the construction were sent to Public Works Department for certification. All the details are provided for the type of building recommended for 27 houses in the coastal habitation of Kodiyampalayam (Panchayat) in Nagapattinam District. SEVAI Foundation reconstructed 600 disaster risk reduction homes as post-disaster of tsunami reconstruction in Poompuhar Tamil Nadu state of India (Govindaraju, 2011). As the villages are located very close to the coast and also at low level, the plinth level is insufficient for future sea level rise.

Jennifer Duyne, University of Zurich and University of Applied Science, Lugano, posed the challenges and risks in post-tsunami housing reconstruction in Tamil Nadu. Though the government has distinguished itself for excellent disaster management, good governance in a post disaster situation is inadequate and cannot overcome all the chronic problems that existed prior to the disaster (NCRC Report, 2005). Information systems and data bases have to be in place to ensure that all operations in the post disaster situation are properly planned and executed.

Special emphasis was laid based on CZR (Coastal zone regulation) guidelines on migration to the new location in order to keep communities together. The selected sites were mostly close to their previous homes but preferably beyond 200 meters from high-tide line as physically observed. GoTN had to perform a balancing act by shifting affected fishing communities to safer places without distancing them from the coast and the sea explaining the importance of relocation. Ankush Agarwal (2007) illustrated the architecture, damaging effects of cyclones, site selection, and design of cyclone resistant structures for Indian Coastal line. The failure components and catastrophic failures of the types of houses are also explained for cyclone prone area.

II. Appropriate Coastal Planning

The increasing frequency and ferocity, the extent of the damage both human and economic the resources required for reconstruction work, all compelled the policy makers and administrators to do a reappraisal of Institutional and policy frameworks and to develop new frameworks for holistic disaster management in India. A legal and institutional framework for disaster management was established through the Disaster Management Act that was passed by the Indian Parliament in 2005 and the National policy on disaster management was approved in 2009. An ideal coastal construction planning for habitation is shown in figure 3 aiming for

- A good lay out at a safely planned long standing land use
- Permanent shelters resistant against EQ, Tsunami/SLR, floods and cyclone
- Coastal protection against erosion,
- Protection for sea water intrusion and Tsunami.
- Prediction and early warning against disasters
- Permanent power supply and exploitation of renewable energy.
- Water supply and drainage forever and common facilities and
- Evacuation structure for emergency

2.1 Coastal Disaster Resistant Structures

Coastal erosion, sea water intrusion, sea level rise, and backwater problems exist throughout the year in the East coast of India. Seasonal hazards and the unexpected Tsunami bring catastrophic, causing heavy loss of lives and properties. Therefore the structure should be oriented for resistance against the coastal forces with properly shaped and designed as EQ resistant. Various house plans that divert the tsunami waves are given in figure 4.

Specific design principles for Tsunami should involve distance from the sea and elevation above mean sea level. Engineers are designing methods and techniques to design a building on columns for coastal areas where Tsunamis can take place. In such cases much attention should be given for earthquake resistance. Reinforced concrete buildings obviously will be cyclone resistant. Therefore a reinforced concrete type is more suitable for coastal disaster resistant structure.

2.2 Control system

A conceptual controlled design shall be developed for coastal zone (figure 5) by a proper permanent protection system including disaster warning system, land use planning and Tsunami evacuation system incorporating several elements as follows:

- A complete protection by bio-shield having mangroves and woodlands
- Proper land use planning (atleast 1km away from the coast line)
- A evacuation building(EB) with salient features
- The EB should be raised on columns to allow seawater to pass beneath the structure and open in other times to make activities.
- The safe floor level shall be set above the most of the rare tsunami events.
- A roof terrace shall be designed to provide more refuge area.
- Exterior stairs should be visible to easily identify the evacuation building.
- The lower level accessibility shall be planned with the use of elevators designed to be functional after the earthquake.
- Strategies for wave energy dissipater to reduce tsunami actions on the TEB can be provided.
- Exploitation of renewable energies can be promoted

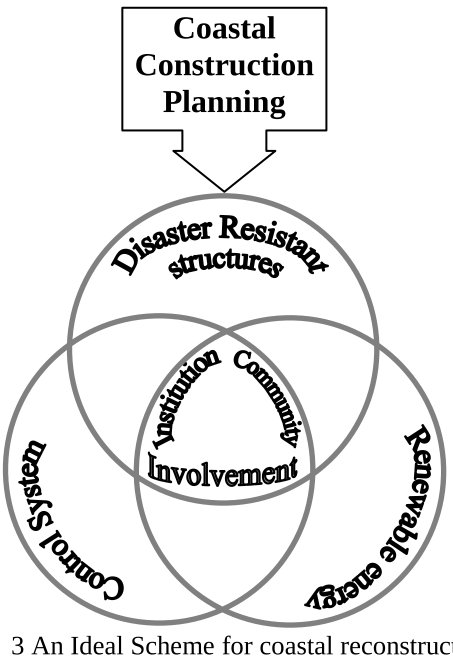


Fig. 3 An Ideal Scheme for coastal reconstruction

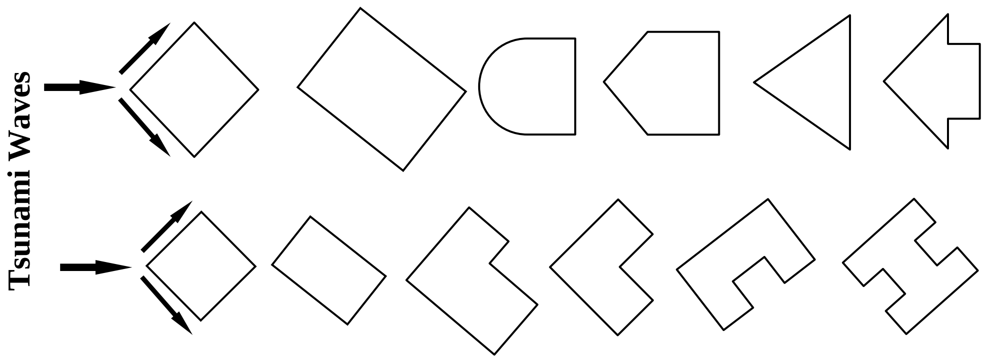


Fig.4 Appropriate single / multiple house plans for Tsunami resistantance

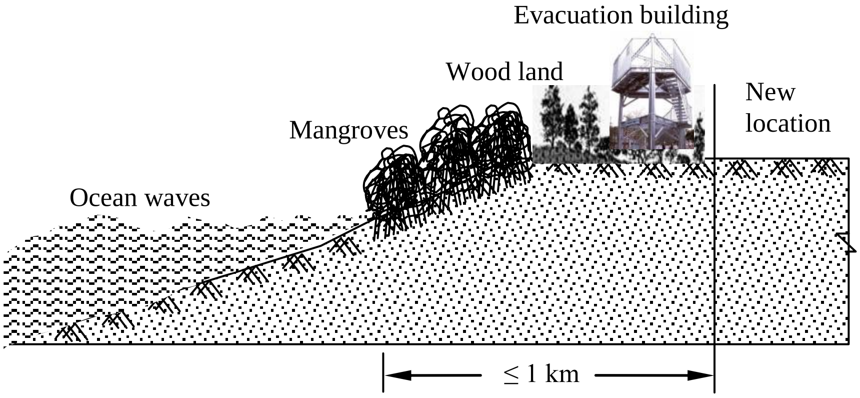


Fig. 5 An ideal plan for a reconstruction with control system

A coastal protection system should be cost effective unlike sea walls. There is not much attention given to coastal protection in Indian coastal line. Only in few locations sea erosion was protected by several means of provisions like fencing with cut palm trees, walling with stone boulders and development of mangrove forests. Sundar and Sundaravadivelu (2005) have made a survey for the Tamil Nadu coastal line to study the shore conditions after the 2004 Tsunami and discussed the suitable protection measures. Variety of methods has been suggested for shore protection and bio shield seems to be more appropriate for the east coast. Human inhabitation should be encouraged more than 1km from the shoreline in elevated places, behind dense mangroves and or other coastal vegetation. Some plant species, suitable to grow in between human inhabitation and the sea for coastal protection.

2.3 Renewable energy

Acute shortage of conventional power will be experienced by all the countries in future and several countries have already started exploiting the non-conventional renewable energies. Among the renewable energies, solar energy can be the best choice and help including distributed power, solar cookers, water sterilization, distillation, and desalination (Yogi Goswami, 2005). Solar photo voltaic (PV) systems provide the fastest way for reestablishing power for electricity needs of appliances and light in some affected areas. Solar distillation and desalination systems can make clean water from the sea water. The biggest solar garden of Asia is installed at a remote village (Saranga) of Gujarat state of India. The roof of a building installed with solar panels can produce up to 150 kW of electricity in each building. As India is having maximum summer and more exposure of sun light, exploitation of solar energy can serve the next generation in the coastal line. The power requirement can be computed for an individual house and the solar panels can be accordingly designed and installed. The government of India has come with the supply of appliances at subsidiary rate. Therefore a solar energy system can be designed for a coastal layout to have continuous power supply.

2.4 Community Participation

Community participation has been recognized as an important element in disaster management to build disaster resilient communities and the desired characteristics of tsunami resilient communities have been well understood. Lorna (2009) highlights the features, processes, components and gains of community based disaster management showcased in Philippine (one of the world's most disaster-prone Asian countries, having identified almost eight disasters a year). People's awareness of what to do at the event of an EQ and tsunami and regular conduct of exercises/mock drills helped them in Japan during 2011 Tsunami. The expectations after a disaster will be high for an affected coastal community towards the reconstruction. However community participation will lead to better coastal planning and management.

2.5 Institutional Participation

SEEDS India (Social Economic Educational Development Service) has developed a methodology for school safety in India and tested the methodology in about 500 schools in various parts of India which are prone to natural hazards. Considering school-specific hazards, teachers and students are guided to develop a disaster management plan for mitigation, preparedness and response. Such education, conducted before the 2011 tsunami, guided the pupils at schools in Ishinomaki (city completely washed away in Japan) to successfully escape from tsunami.

The School children of Tsunami affected region in Villupuram district of Tamil Nadu state are engaged in educational trips and given awareness training about the disasters. 20 such trips with at least 200 children in each trip benefited by this programme. Types, causes and management of disasters, does and don’ts, use of solar and wind energy, impact of sea level rise etc. were discussed. Model tests were conducted to check whether adequte awarness be created in their minds about the disaster management. This approach by the department of Structural Engineering, Annamalai University has attracted the people as well as other institutions around. This department has offered typical projects through post-graduate and doctoral reaserch programmes to identify problems and provide a permanent solution for the disaster management in the coastal zone (Balamurugan, 2012). Many similar activities can be planned by the near by institutions and projects formulated towards a safer and better longstanding disaster free coastal habitation. For a rural based coastal line the Institutional participation can help the downtrodden coastal community. Decision-making in an interactive and co-influencing learning arena is very essential and requires institutional adaptation.

2.6. Proposed Model Houses

Tsunami resistane houses suitably planned and recommended for a rural coastal rehabilitation are shown in figures 6 and 7. These houses will have utilities as listed.

- The building is designed as EQ/Tsunami/cyclone/flood resistant type of RCC.
- Corrosion free Fibre reinforced Polymer rebars are used instead of conventional steel
- The building is raised on columns to allow seawater to pass beneath the structure (soft story) and open in other routine times to make multipurpose.
- Disaster information and alert system is accessible for the people of the house
- The Terrace level is set above the most of the rare tsunami events.
- Terrace is designed to provide additional accommodation.
- Emergency power supply is made possible with the solar/wing energy.
- Water supplied from elevated water tank is directly discharged in to the small capacity water tank provided at the terrace in each house.
- Desalination plant is available in each housing unit.

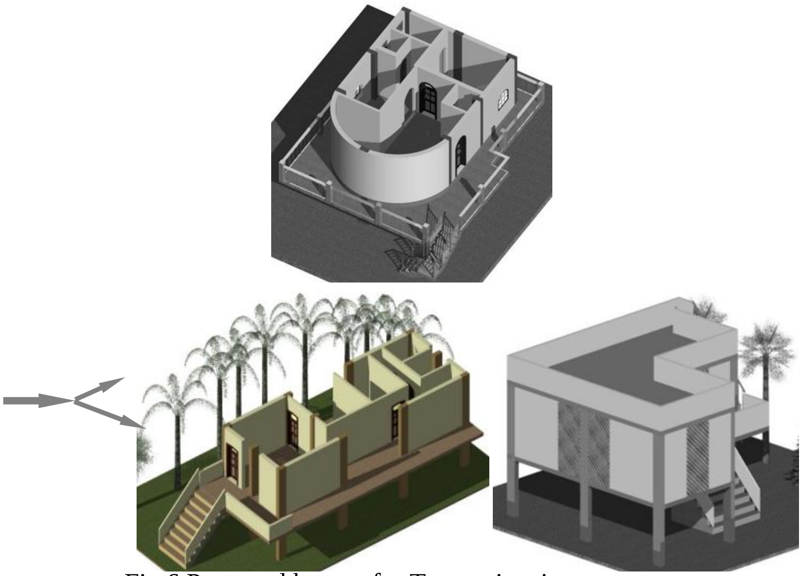


Fig.6 Proposed houses for Tsunami resistance

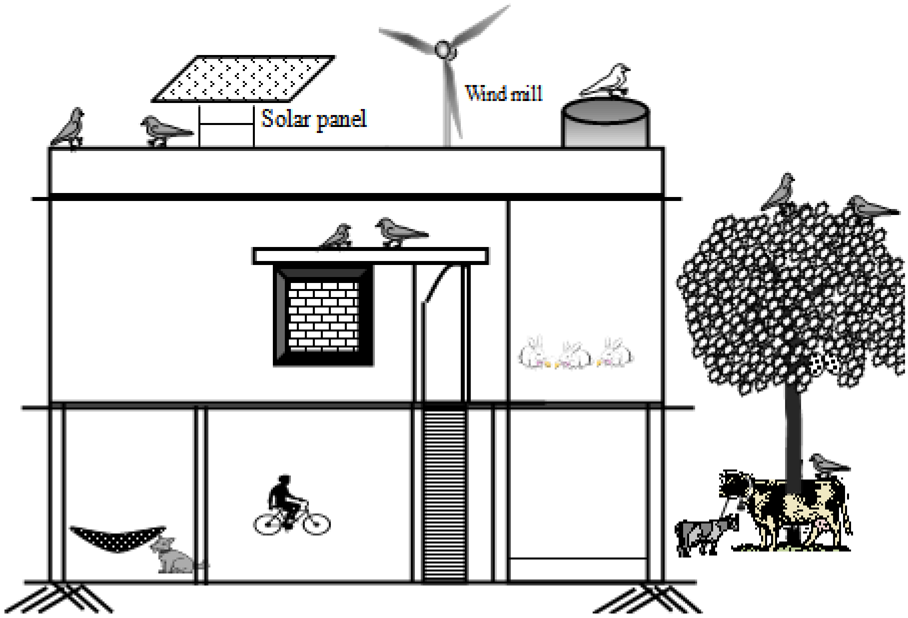


Fig.7 Appropriate house for Rural Coastal area

III. Conclusion

The coastal disasters and sea level rise, scarcity of construction materials and skilled labors, shortage of conventional power and fuels, industrialization of coastal area, rapid growth of the coastal population, mass employment problem, lack of motivation to the coastal society and some extent of corruption lead to a slackness in promoting the disaster mitigation programme. Loss of life and property by the Tsunami of 2004 could have been avoided if the coastal zone management was properly understood and implemented. The better land use planning, innovative architecture and appropriate technologies of disaster resistant structural constructions have helped the affected community by the post tsunami reconstruction. As it is lagging in many aspects, and based on the thorough literature collection and review, a better plan for the next generation with a control system proposed has been explained. The construction plan with control system that include land use planning, coastal protection system, disaster resistant structure, evacuation system, disaster warning system, exploitation of renewable energies, effective community participation and institutional contribution can only fulfill the total requirements for better coastal planning.

References

[1] Alpa Sheth, Snigdha Sanyal, Arvind Jaiswal and Prathibha Gandhi (2006). "Effects of the 2004 Indian Ocean Tsunami on the Indian mainland", Earthquake engineering research institute, Earthquake Spectra, Vol.22, No.S3. pp. S435–S473.

[2] Anbarasu, K and Rajamanickam, G.V (1997). "Abandoned channels of rivers- An evidence of neotectonism", Indian Journal of Geomorphology, Vol.2, pp. 209-217

[3] Ankush Agarwal (2007). "Cyclone resistant building architecture", GOI-UNDP Disaster risk management programme, Government of India.

[4] Balamurugan, R (2012). "Disaster Management in Tsunami Affected Portonovo Beach", Ph.D Report, Annamalai University, INDIA.

[5] GoTN Report (2008). "Tiding over TSUNAMI-Part 2", October 2008, Government of Tamil Nadu, India.

[6] Govindaraju, K (2011). "Poompuhar Safer Homes -Post-Tsunami Disaster Reconstruction Programs"- SEVAI/FdnF/UWI, News Line, Trichy News, NGO News, Wednesday, May 11, 2011.

[7] IOM Report (2005). "IOM Post-Tsunami Shelter Operations - Indonesia and Sri Lanka", International Organization for Migration, Geneva, Switzerland.

[8] Janakarajan, S (2009). "Challenges and Prospects for Adaptation: Climate change and Disaster risk reduction in coastal Tamil Nadu, Working with the winds of change", Chapter 9, Case study guidance note, pp. 236-270.

[9] Jayasuriya, S., Steele, P., Weerakoon, D., Knight-John, M. and Arunatilake, N (2005). "Post-Tsunami Recovery: Issues and

Challenges in Sri Lanka”, Asian Development Bank Institute (ADBI), Tokyo — Discussion Paper.

[10] Jay Raskin, Yumei Wang, Marcella M. Boyer, Tim Fiez, Javier Moncada, Kent Yu, and Harry Yeh (2009). “A New Risk Management Approach to Cascadia Earthquakes and Tsunamis”, Preliminary White Paper on Tsunami Evacuation Buildings (TEBs)

[11] Jay Shafer (2008). “Small House Book”, Tumbleweed Tiny House Company.

[12] Jennifer Duyne Barenstein and Daniel Pittet (2007). “Post-disaster housing reconstruction Current trends and sustainable alternatives for tsunami-affected communities in coastal Tamil Nadu”, research project report, ISAAC, pp. 1-16.

[13] Kathiresan, K and Rajendran, N (2005). “Coastal mangrove forests mitigated tsunami. Estuarine”, Coastal and Shelf Science, Vol.65, pp. 601–606.

[14] Lorna P. Victoria (2009). “Community Based Disaster Management in the Philippines Making a Difference in People’s Lives”, Proceedings, Regional Workshop on Best Practices in Disaster Mitigation-Community-Based Approaches to Disaster Mitigation, Bangkok pp. 269-290.

[15] Murty, C. V. R., Sudhir K. Jain., Alpa R. Sheth., Arvind Jaiswal and Suresh R. Dash (2006). “Response and recovery in India after the December 2004 great Sumatra Earthquake and Indian Ocean Tsunami”, Earthquake Engineering Research Institute, Earthquake Spectra, Vol.22, No.S3, pp. S731–S758.

[16] NCRC Report (2005). “Snapshot of Damages Due to Tsunami: Village-wise in Nagapattinam District”, NGO Coordination and Resource Centre (NCRC), Nagapattinam, Tamil Nadu, India (An initiative SIFFS, SNEHA and UNDP supported by District Administration, Nagapattinam, TN, India)

[17] Pittet, Daniel, Barenstein and Jennifer Duyne (2007). “Post-disaster housing reconstruction: Current trends and sustainable alternatives for Tsunami-affected communities”, Institute for Applied Sustainability to the Built Environment, University of Applied Sciences, Southern Switzerland .

[18] Prabhakar, Y.S., Potha Raju, M and Manjulavani, K (2011). “Civil engineering aspects of tsunami resistant buildings: A Forensic approach”, The IUP Journal of Soil and Water Sciences, Vol.IV, No.3, pp. 48-63.

[19] Regan T. Potangaroa (2006). “GIMME shelter: Tsunami mitigation as part of a permanent shelter program for Aceh, North Sumatra”, Report, Department of Architecture, Unitec, Auckland NZ.

[20] Renata D’Aliesio (2011). “Engineers goal is tsunami-resistant buildings”, Monday's Globe and Mail, 2011, http://www.theglobeandmail.com/news

[21] Satoko Oki and Kazuya Nakayachi (2012). “Paradoxical effects of the record-high tsunamis caused by the 2011 Tohoku earthquake on public judgments of danger”, International journal of disaster risk reduction. (Available online)

[22] Sundar and Sundaravadivelu, R (2005). “Protection Measures for Tamil Nadu Coast”, Final Report Submitted to Public Works Department, GoTN.

[23] Ventasal (2012). “Tsunami resistant house building design example”, House design and interior design talks for Dream home**,** March 25, 2011.

[24] Wilkinson, T (2005). “Report on coastal design and Tsunami mitigation for shelter/house reconstruction along west coast”, Aceh Province pub. UNHCR.

[25] Yogi Goswami (2005). “Solar energy systems will provide tsunami disaster relief”, View point, (International Solar Energy Society), www.refocus.net.